GROWTH RESPONSES OF OSMOTICALLY STRESSED SEEDLINGS OF *ABIES PINDROW* UNDER DIFFERENT LIGHT REGIMES

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ABSTRACT

Two month old seedlings of *Abies pindrow* were subjected to three water stresses (-0.04, -0.4, and -0.8 MPa) created by the addition of osmoticum (polyethylene glycol 6000) to nutrient solution under three levels of light (50, 125 and 250 μ mol m^{-2} s^{-1}) in the phytotron. Compared to the control seedlings, growth in terms of net photosynthesis, was significantly reduced (57 percent) for seedlings subjected to High light and the severest water stress. The light use efficiency of seedlings was greatest under Low light and moderate and severe water stresses. The results indicated that after two weeks transpiration and stomatal conductance were significantly reduced by High light and high water stress treatment; while the needle water potential of -2.0 MPa under these conditions did not result in complete stomatal closure.

INTRODUCTION

Water stress plays an important role in survival, growth and distribution of plant species. Young seedlings are particularly sensitive to water stress because of their small, underdeveloped root systems (Brix, 1979), and often develop severe water deficits (Davies *et al*. 1973). Stress reduces growth. Cell enlargement is particularly sensitive to water deficit (Jones, 1986).

The importance of light on various physiological processes such as net photosynthesis, transpiration, stomatal conductance, light and water use efficiency is well documented (e.g. Bidwell, 1987; Jones, 1986 and Hart, 1988). The role of light quality (red/far red ratio) influence on net photosynthesis and ultimately on the growth of natural seedlings has been emphasized by Hart (1988); Jones (1986) and Kwesiga *et al*. (1986).

Desiccation is often one of the most important threats to the survival of newly planted conifer seedlings (Blake and Sutton, 1987; Grossnickle, 1988). The ability of seedlings to tolerate drought is strongly influenced by their prior life history. Exposing plants to one stress frequently not only confers a tolerance to a more severe dose of the same stress but also to other environmental factors (Levitt, 1980). Other work has emphasized the importance of root growth for the survival of young *Abies* seedlings under water stress (e.g. Alexander, 1987; Knapp and Smith 1981; Van den Driessche, 1987).

Haq (1992) reported that the highest level of light (in canopy gaps) at Kund experimental site during summer is 180 μ mol m^{-2} s^{-1} which is about half of that required for light-saturation (350 μ mol m^{-2} s^{-1}) of net photosynthesis of seedlings. It was also observed that seedling growth under a low light regime (caused, by shade either from *Viburnum* or from *Trees plus Viburnum* cover) should not result in mortality during the growing season. However field observations showed high mortalities in late May and June. One important factor for the survival in forest is likely to be the availability of water before the start of monsoon. This becomes more important as irradiance increases and the soil dries out in May and June.

The study described in this paper was designed to investigate the interactions between light and moisture which might play an important role in the mortality of seedlings in natural stands.

MATERIALS AND METHODS

Experimental design

The experiment was laid out in a replicated factorial design, using three PAR (Photosynthetically active radiation) levels and three levels of water stress (i.e. nine treatments in total) with four replications (plants) per treatment.

Details of the experimental treatments are shown in Table 1. The air temperature was kept at 25° C and 20° C for day and night times respectively. These temperatures represent average monthly maxima and minima for May and June at Kund for the years 1988 and 1989. PAR levels chosen to study represent the three conditions generally experienced in the natural stands during June each year. Low light under *Vibernum* and Tree Plus *Viburnum*, Medium under Tree cover and High in canopy gaps.

Table 1: Details of different PAR and water-stress treatments.

PAR levels	PAR (μ mol m^{-2} s^{-1})	Stress levels* (MPa)	Remarks
Low	50	-0.04	Control (no stress) (S1)
Medium	125	-0.4	Stress condition, generally experienced after small showers of rain in the field (S2)
High	250	-0.8	Representing severe stress under drought conditions (S3)

* Water potential of culture solutions.

The observations of soil water potential recorded in 1989 in the top 4 to 5 cm of soil ranged from -0.6 MPa to -0.99 MPa and hence -0.8 MPa was selected to represent severe drought conditions.

Plant material and growth conditions

Thirty six seedlings of *Abies pindrow*, two months old and 3 to 4 cm tall, were fitted in punched tops of black pvc boards placed on 4.5 litre plastic pots (Fig. 1) containing commercially aerated nutrient solution. Nine containers were used each with 4 seedlings. The pierces holding the stems of the seedlings were completely sealed with non absorbent cotton to prevent penetration of light to the solution.

The nutrient solution was prepared in deionised water (0.55 ml nutrient solution per

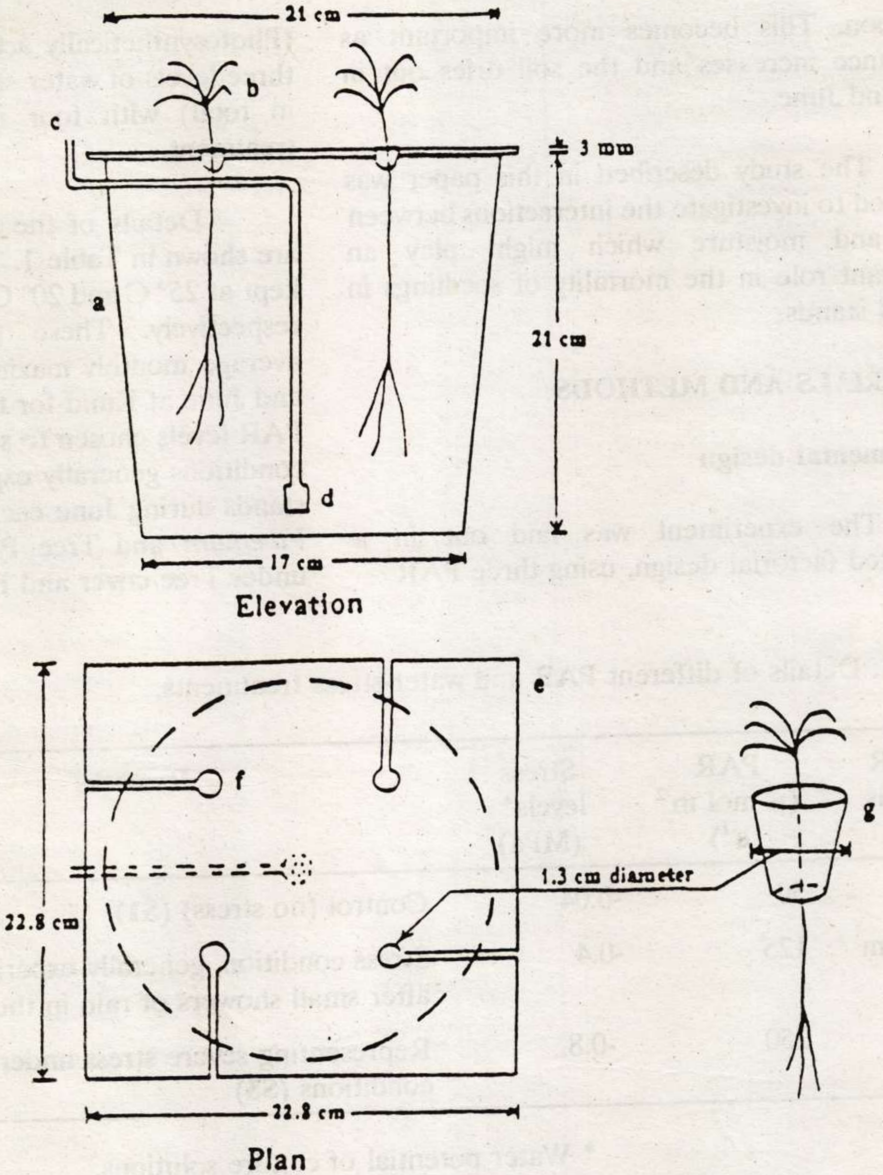
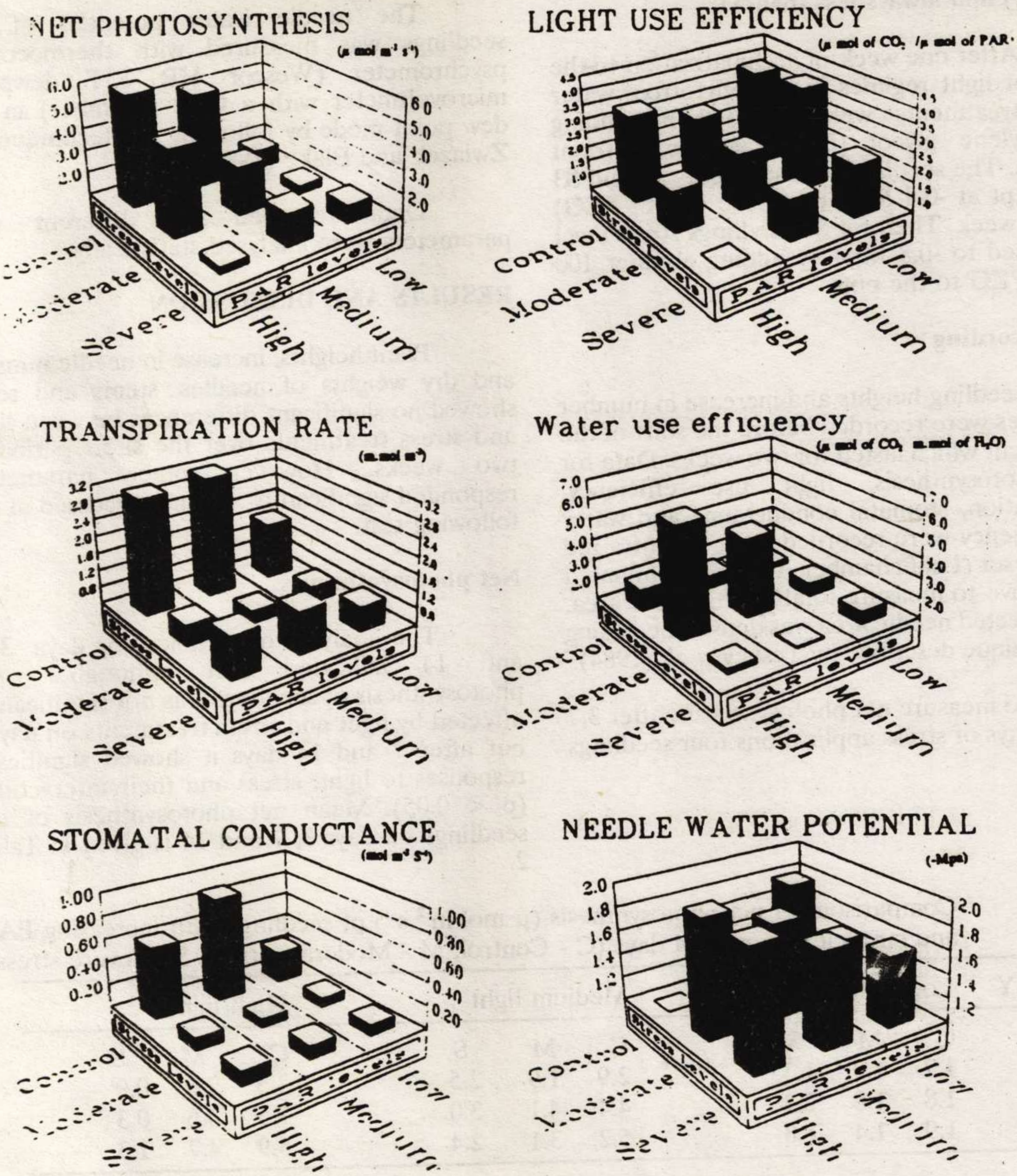


Fig. 1: Plastic containers used for growing *Abies pindrow* seedlings in nutrient solution in the phytotron experiment at Oxford.

a - 4.5 litre container.
b - Seedling fitted in slotted rubber bung (sealed with non absorbent cotton).
c - Aeration tube.
d - Aeration diffuser.
e - Black PVC board (3 mm thick).
f - Hole for placement of seedling.
g - Slotted rubber bung with seedling.

Fig. 2 Summary of physiological parameters under 3 light and stress levels on day 14 of treatment.



litre) at 4.5 pH. The basic composition was: total nitrogen (5 %), phosphorus (5 %), potassium (5 %) with appropriate micronutrients. The pH of the solution was monitored with every change of solution (weekly) and always less than 5.0.

After one week of acclimatization to the different light regimes in the phytotron, water stress treatments were imposed by adding polyethylene glycol (PEG) to the nutrient solution. The seedlings of treatments S2 and S3 were kept at -0.4 MPa (with 135 $g.l^{-1}$ of PEG) for one week. Then for S3 seedlings stress level was raised to -0.8 Mpa by adding another 100 $g.l^{-1}$ of PEG to the pots.

Data recording

Seedling heights and increase in number of needles were recorded before the start of the experiment which lasted for two weeks. Data for net photosynthesis, light use efficiency, transpiration, stomatal conductance and water use efficiency were recorded using an Infra red gas analyser (Leaf chamber ADC-3) illuminated from above to measure total plant needle area. The projected needle area was determined using the technique described by Teskey *et al.* (1984).

To measure net photosynthesis, after 3,7 and 14 days of stress applications four seedlings treatment were moved (for 10 to 15 minutes) to small bottles containing the growing medium to facilitate the measurements inside the phytotron.

The needle water potential of the seedlings was measured with thermocouple psychrometer (Wescor HR 33T dewpoint microvoltmeter with a C-52 Chamber) in the dew point mode by following the techniques of Zwiazek and Blake (1989).

Data recorded for different said parameters were analysed statistically.

RESULTS AND DISCUSSION

Plant heights, increase in needle number and dry weights of needles, stems and roots showed no significant differences between light and stress treatments over the short period of two weeks. However, other parameters responded significantly and are discussed in the following text.

Net photosynthesis

The analyses of variance for days 3, 7 and 14 indicated that although net photosynthesis of seedlings was not significantly affected by light and stress treatments on day 3, but after 7 and 14 days it showed significant responses to light, stress and their interactions ($p < 0.05$). Mean net photosynthesis of the seedlings on days 3, 7 and 14 is given in Table 2.

Table 2. Comparisons of net photosynthesis (μ mol m^{-2} s^{-1}) of seedlings with increasing PAR and stress levels over 14 days (C - Control, M - Moderate stress, S - Severe stress)

DAY	Low light			Medium light			High light		
	C	M	S	C	M	S	C	M	S
3	1.7	1.3	1.3	2.9	1.9	2.5	3.5	2.6	0.9
7	1.8	1.8	2.2	4.4	4.1	3.0	7.5	4.6	0.3
14	1.9	1.4	1.8	5.2	3.1	2.4	5.9	4.7	1.3

Net photosynthesis of moderate and severely stressed seedlings was lower than control, with greatest decrease on day 14 for each light regime, with a minimum (except on day 7) in Low light. During a severe drought water stress becomes important through its influence on stomatal closure resulting in consequent reduction of net photosynthesis (Jones 1986; Young and Smith. 1980). Under controlled conditions the highest level of light (250 μ mol m^{-2} s^{-1}), in combination with a moisture stress (-0.8 MPa), resulted in 57 percent reduction of net photosynthesis as compared to control. This suggests that seedling mortality is likely to increase in severe droughts during hot summers in the natural stands as earlier reported by Haq, (1992).

Light use efficiency

Analyses of variance for the light use efficiency of the seedlings showed that light had a significant effect on all the three days, while stress was significant on days 7 and 14 However, their interaction was significant on day 7 ($p < 0.05$) only. The light use efficiency of seedlings under the three light regimes was also significantly affected by the light levels. The improved light use efficiency of low light seedlings reported by various researchers e.g. Jones, 1986, Crawford, 1989 and Ridge, 1991.

Transpiration

Transpiration was significantly affected by stress and light while their interaction was significant on day 7, and by stress and light on day 14 ($p < 0.05$). Transpiration tended to be higher in control plants than in stressed plants. The moderately and severely stressed seedlings showed variable behaviour in response to changing light. The transpiration rates of the moderately stressed seedlings were more affected by light levels than those of the severely stressed ones. The transpiration rates of *Abies pindrow* seedlings were affected at a water potential of -2.0 MPa as compared to control which is similar to the findings of Lopuskiky and klock (1974) for *Abies grandis* seedlings.

Stomatal conductance

The analyses of variance for stomatal conductance showed that light and stress had significant effects on day 14 showing that the decrease in stomatal conductance was 0.12 mole m^2 S^{-1} as compared to control ($p < 0.05$). Running (1980) mentioned that stomatal activity reponds to different environmental variable namely air, temperature, humidity, radiation and soil water supply as transmitted by the internal plant water status. The water potential of *Abies pindrow* recorded during the experimental period under highlight and severe stress ranged from -1.8 to 2.0 at which no stomatal closure was observed which is contrary to *Abies grandis* seedlings (Lopuskiky and klock (1974).

Water use efficiency

On day 14 water use efficiency of the seedlings was significantly improved by higher light levels, stress levels (moderately stressed showing the highest efficiency) and their interaction (moderately stressed combined with High and Medium light displaying the highest efficiencies) as shown in Fig. 2. Low rates of transpiration of *Abies lasiocarpa* seedlings in high light regimes are responsible for an increase in water use efficiency, (Carter and Smith, 1988). Similarly, Lopushinsky (1969) and Lopushinsky and Klock (1974) found that stomat of lodgepole pine seedlings closed more readily with increasing moisture than those of Englemann spruce.

Fig. 2 provided a summary of different plant parameters affected by various light and water stress levels on day 14 after giving maximum exposure time to each treatment. It revealed that the combined effects of severe stress and high light regime greatly reduced net photosynthesis. These seedlings under high light conditions in *canopy openings* are liable to considerable growth losses during drought periods when compared to seedlings of shrubs and trees under shade. The stomatal conductance as well as transpiration were depressed by stress (-0.8 MPa) These effects may cause mortality in most extreme conditions. It is evident that the effect of severe moisture stress on net photosynthesis is least for seedlings under low light conditions, suggesting that seedlings on these sites may survive better during times of drought.

CONCLUSIONS

From the findings of presented investigation this can be concluded that under controlled conditions the combined effects of High light and severe stress reduced net photosynthesis as compared to control seedlings but this reduction did not result in their death. Seedling mortality occurred in the field presumably when the stress level exceeded the limits tested in the growth chambers. Seedlings of *Abies pindrow* can tolerate a high level of light and extremes of stress in natural stands.

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